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(54) Expandable polystyrene beads

(57) Polyethylene wax of specified physical properties is used as an additive for expandable polystyrene beads to yield small cell size and fast-molding cycles. The polyethylene is substantially linear, has a molecular weight of 700 to 1500 a very narrow molecular-weight distribution (polydispersity of less than 1.2) density at least 15.4 kg/m³ and m.p. of at least 102°C.

GB 2 110 217 A

SPECIFICATION

Expandable polystyrene

5 The present invention relates to expandable polystyrene. Prior to the present invention, it has been known to employ small amounts of polyolefin wax in expandable polystyrene beads in order to achieve more or less uniform cell size and distribution and a relatively rapid pressure drop when the beads are expanded and molded. For example, United States Patent Specifications Nos. 3,224,984 and 3,398,105 disclose the admixture of finely divided polyethylene or polyethylene wax in a concentration of, typically, 0.1 to 0.5 percent. The polyethylene disclosed in the aforementioned patents has a molecular weight of 1000 to 4000. It is said that, in the absence of the polyethylene, an undesirable quantity of large cells are formed, causing crystallinity.

United States Patent Specification No. 3,060,138 discloses the addition to polystyrene of paraffinic hydrocarbons having 16 to 46 carbon atoms, the paraffinic hydrocarbon being dissolved in an expanding agent, such as, isopentane. Such low-molecular weight materials, however, may be expected to dissolve when contacted by hot liquids, making them undependable for uses such as for coffee cups. United States Patent Specification No. 3,192,169 discloses the use of a paraffin wax which has a melting point of 145°F (63°C) and a density of 0.92 lb/ft³ (14.7kg/m³) at 77°F (25°C), indicating that it contains undesirable non-linearity. It also contains 0.2% oil.

20 It has been found that the use of very specific amounts of polyethylene having very specific characteristics in the manufacture of expandable polystyrene beads provides significant advantages in the subsequent expansion molding of the beads into articles such as cups. Expanded polystyrene cups are made in large quantities, making the duration of the molding cycle an important economic factor. The uniformity and smallness of the cells are also important. In addition, finished expanded bead cups desirably have to retain their stiffness as well as impermeability when holding hot liquids such as coffee.

In a search for smaller cell size and faster molding cycles, the performance of a series of low-molecular-weight homopolymers of ethylene having various molecular weights and narrow molecular-weight distributions was evaluated. It was found that certain polyethylene waxes having linearity (almost no branching) and narrow molecular-weight distribution singularly different from any other commercially available polyethylene were excellent modifiers of polystyrene. The main factors controlling their unique physical properties are: low-molecular weight (that is 700 to 1500), linear molecular structure, and very narrow molecular-weight distribution. The polydispersity (an index of molecular-weight distribution calculated by dividing the weight-average-molecular weight by the number-average molecular weight) is less than 1.2. Due to the absence of side chain branching, plus the narrowness of molecular-weight distribution, these polyethylene waxes differ significantly from other polymers in such physical characteristics as density, melting point, solubility, melt viscosity, hardness and crystallinity. Their density is at least 0.96 lb/ft³ (15.4kg/m³) and melting point at least 215°F (102°C). Because of the absence of a higher molecular weight fraction, melting point and viscosity are lower than other typical polyethylenes of the same average molecular weight. Also, the absence of very low molecular weight fractions makes the materials harder and permits them to retain their hardness and insolubility at relatively high temperatures. The linearity, or lack of molecular branching, results in a higher density, more crystalline polymer.

Accordingly, therefore, to the present invention, there is provided a method of making expandable polystyrene beads comprising a polymerizing styrene monomer in a reaction mixture containing 0.05% to 0.5%, by weight based on the styrene, of a polyethylene wax, and impregnating the beads with a blowing agent, said polyethylene wax being substantially linear and having a density of at least 0.96 lb/ft³ (15.4kg/m³), a molecular weight of 700 to 1500, a polydispersity of less than 1.2, and a melting point of at least 215°F (102°C).

The invention also provides expandable polystyrene beads containing a blowing agent and 0.05% to about 0.5%, by weight based on the polystyrene, of a polyethylene wax, said polyethylene being substantially linear and having a density of at least 0.96 lb/ft³ (15.4kg/m³), a molecular weight average of 700 to 1500, a polydispersity of less than 1.2, and a melting point of at least 215°F (102°C).

Polyethylene wax having a weight average molecular weight of 1000 and a melting point of 235°F (113°C) was most effective (on a weight basis) in reducing cell size; both higher and lower molecular weights were less effective. The existence of an optimum molecular weight for cell size is unknown in the prior art, which generally employs polyethylenes of broader molecular-weight distributions. It was also found that faster molding cycles were obtained as the concentration of additive was increased, up to about 0.5 weight percent. At least about 0.05 weight percent is necessary to produce any appreciable benefit.

Example 1

60 A suspension polymerization run was conducted in an aqueous suspension with styrene monomer, 0.2 weight percent polyethylene having a weight average molecular weight of 840, a water insoluble polymerization initiator (peroxide), a suspension agent and a surfactant. The polymer was formed as a slurry of finely divided beads. These beads were recovered, after acidification to destroy the suspension agent, by centrifugation. The beads were then dried in a rotary air dryer. The beads were then impregnated with a blend of n-pentane and isopentane (70-30) at an elevated temperature in an aqueous suspension.

Suspension agent was added before the start of the impregnation cycle. The beads were then recovered by centrifugation and dried in an inert atmosphere. The beads were then classified to remove fines before storage. In a subsequent molding process, the beads were pre-expanded in a Rodman-type pre-expander, aged in open bags in air and then steam expanded in a mold and press to make the finished article. The pre-expanded "prepuff" had an average cell size of 100 microns. Fast molding cycles were obtained in the molding process. Cups made in this manner were well fused, had a desirable non-crystal surface, were resilient when the cups were squeezed, and did not weep hot coffee.

Example 2

The procedure of Example 1 was repeated using 0.12 weight percent 840 weight average molecular weight and 0.08 weight percent 1200 weight average molecular weight polyethylene wax. Small cells were obtained in the "prepuff" and molding cycles were short.

Example 3

The procedure of Example 1 was repeated without any polyethylene. The resulting "prepuff" had a cell size of 130 microns, and the molding cycles were long.

Example 4

The procedure of Example 1 was repeated using 0.2 weight-percent 8000 weight average molecular weight polyethylene. The "prepuff" had very large cells; 240 microns average.

Example 5

Example 1 was repeated using 0.1 weight-percent polyethylene wax having a weight average molecular weight of 1000. The resulting "prepuff" had a cell size of 70 microns.

Example 6

The procedure of Example 1 was repeated using 0.2% polyethylene wax having a weight average molecular weight of 1000. It yielded a "prepuff" having a cell size of 20 microns.

Example 7

The procedure of Example 1 was repeated using 0.2% of a polyethylene wax having a weight average molecular weight of 840, yielding a "prepuff" with a cell size of 100 microns.

Example 8

Expandable polystyrene beads were made according to Example 1 except that a fire-retarding agent was added during manufacture and n-pentane was used as blowing agent. The beads were pre-expanded in a Rodman-type steam pre-expander and aged in air for twenty-four hours. An aged density of 1.5 lbs/ft³ (24kg/m³) was obtained. The beads were then molded at various molding pressures as were prior art beads of a typical commercial composition. The overall cycles were as follows:

Overall Cycle

	Molding-Cycle Component	Time, seconds	
45	Mold Closing	4	45
	Filling	5	
	Steaming	5	
50	Steam Dwell	2	50
	Cooling	see below	
55	Water Blowout	1	55
	Delay Open	2	
	Mold Opening	4	
60	Total cycle time	23 seconds + cooling time	60

Cooling Component of Cycle

		<i>Molding Pressure, bars</i>	<i>Cooling Time, seconds</i>	
5	<i>Prior art</i>	2.25	35	5
		2.39	35	
		2.53	55	
10		2.67	55	10
	<i>Invention</i>	2.25	7	
15		2.39	7	15
		2.53	33	
		2.67	52	

Example 9

Expandable polystyrene beads were made according to Example 1 but using 0.2 weight percent 1000 molecular weight polyethylene wax and n-pentane as blowing agent. The beads were pre-expanded in a Rodman-type pre-expander and aged for twenty-four hours in air. An aged density of 1.4 lb/ft³ (22.4kg/m³) was obtained. The beads were then transferred to a billet mold (20 in. x 4 ft. x 8 ft. (51 cm x 122 cm x 244 cm)) and molded at 10 seconds presteam and a maximum of 20 seconds steam (total 30 seconds heading cycle). The following cooling times were obtained:

	<i>Composition</i>	<i>Cooling Time</i>	
30	<i>Invention</i>	2 min. 56 sec.	30
	<i>Commercial material</i>	4 min. 50 sec.	

Example 10

Expandable polystyrene beads were made according to Example 1. The beads were pre-expanded in a Rodman-type steam pre-expander and aged in air for twenty-four hours. An aged density of 1.3 lb/ft³ (20.8kg/m³) was obtained. The beads were then molded at 18 psig (2.25 bars) molding pressure. The overall cycles were as follows:

	<i>Molding-Cycle Component</i>	<i>Time, seconds</i>	
40	Mold Closing	4	40
	Filling	5	
	Steaming	5	
	Steam Dwell	2	
45	Cooling	see below	45
	Water Blowout	1	
	Delay Open	2	
	Mold Opening	4	
	Total cycle time	23 seconds + cooling time	
50			50
	<i>Composition</i>	<i>Cooling Time, sec.</i>	<i>Total Cycle Time, sec.</i>
	0.1 wt.% 1000 M wt. PE	60	83
55	0.2 wt.% 1000 M wt. PE	60	83
	0.2 wt.% 0.08% 1000 M wt. PE 0.12% 840 M wt. PE	60	83
60	0.2 wt. % 8000 M wt. PE	75	98
	<i>Prior Art</i>	75	98

65 M wt. PE = weight average molecular weight polyethylene wax.

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CLAIMS

1. A method of making expandable polystyrene beads comprising polymerizing styrene monomer in a reaction mixture containing 0.05% to 0.5%, by weight based on the styrene, of a polyethylene wax, and
5 impregnating the beads with a blowing agent, said polyethylene wax being substantially linear and having a density of at least 0.96 lb/ft³ (15.4kg/m³), a molecular weight of 700 to 1500, a polydispersity of less than 1.2, and a melting point of at least 215°F (102°C).
2. A method as claimed in claim 1, in which the polyethylene wax has a molecular weight of 1000 and a melting point of 235°F (113°C).
- 10 3. Expandable polystyrene beads containing a blowing agent and 0.05% to about 0.5%, by weight based on the polystyrene, of a polyethylene wax, said polyethylene being substantially linear and having a density of at least 0.96 lb/ft³ (15.4kg/m³), a molecular weight average of 700 to 1500, a polydispersity of less than 1.2, and a melting point of at least 215°F (102°C).
4. Expandable polystyrene beads as claimed in claim 3, in which the polyethylene wax has a molecular
15 weight of 1000 and a melting point of 235°F (113°C).
5. A molded article made from the expandable beads of claim 3 or claim 4.
6. A method of making expandable polystyrene beads, as claimed in claim 1, substantially as described in any of Examples 1, 2 and 5 to 10.
7. Expandable polystyrene beads as claimed in claim 3 made substantially as described in any of
20 Examples 1, 2 and 5 to 10.

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